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Applicant: Eero Suomi et al.

Date: September 7, 2004

Date Filed: Simultaneously herewith

Docket No.: FORSAL-94

PCT App. No.: PCT/FI03/00174

For: Nip Roll of A Paper or Board Machine

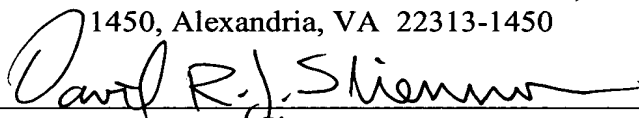
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David R. J. Stiennon, Reg. No. 33212

Name of applicant, assignee or Registered Representative

**Submission of Substitute Specification Under 37 C.F.R. § 1.125**

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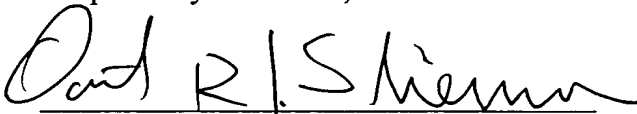
Dear Sir:

A substitute specification, excluding the claims, is filed herewith under the provisions  
of 37 C.F.R. § 1.125(b).

1. The substitute specification contains no new matter.
2. A marked-up copy of the substitute specification showing the matter being  
added to and the matter being deleted from the specification of record  
accompanies this paper. The matter being added is underlined and bold, and  
the matter being deleted is shown struck out, enclosed in brackets and bold.
3. The substitute specification is submitted in clean form without markings as to  
amended material.

Applicant requests that the accompanying substitute specification be entered in the  
application record.

Respectfully submitted,



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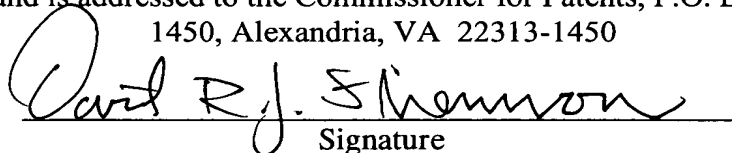
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**Clean Copy of Substitute Specification under 37 C.F.R. 1.125(c)**

TITLE OF THE INVENTION

Nip Roll of A Paper or Board Machine

#### CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application is a U.S. National Stage application of International App. No. PCT/ FI03/00174, filed Mar. 7, 2003, and claims priority on Finnish Application No. 20020465, Filed Mar. 13, 2002.

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER  
FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0002] Not applicable.

## BACKGROUND OF THE INVENTION

[0003] The invention relates to nip rolls of paper or board machines.

[0004] JP-A-52121510 discloses a nip roll of a paper machine which is manufactured of steel.

5 [0005] Various calendering concepts are known from prior art, one of which is long nip calendering. Long nip calendering can be based on shoe press technology or on belt/roll technology. In shoe calendering, shoe press technology known from the press section is used and the shoe roll comprises a shoe, loading elements, a lubricating oil system and a belt. A thermo roll is used as the other roll of the  
10 calendering nip, which roll can be a water-, steam-, oil-, or induction-heated roll. A belt calender comprises a thermo roll, a belt loop and a backing roll, which may be either a hard or a soft roll, and the belt circulates over the backing roll and the guide/tension rolls. In the long nip calendering process large amounts of heat are transferred from the thermo roll to paper and the great heat amounts generate high  
15 thermal stresses and rapid stress gradients in the thermo roll, in which case the properties (durability) of the cast iron rolls used at present are no longer sufficient for the desired process conditions. In addition, the stress states in the roll during its use may vary in the direction of thickness of the material of the roll, to which the materials used today, e.g. chill casting, are poorly resistant.

20 [0006] In today's paper and board machines the calendering process is often connected as an on-line unit to a paper or board machine, in which case, e.g. the changing and cleaning of the roll have to take place quickly in order to avoid wasting valuable capacity. This is problematic, since, according to industrial safety regulations, the temperature of a hot roll must be under 60°C before it can be  
25 changed and, on the other hand, the working temperature of the roll is as high as 200°C. Prior art chilled rolls withstand a temperature change rate of 2°C/min., due to which a considerable amount of time and capacity has been lost in connection with the changing or cleaning of the roll. This has even partly led to the attempt to clean

the rolls quickly, for example with a pressure washer, with the result that the roll cools down too quickly with respect to its strength, and thus serious damage may have been caused to the roll.

5 [0007] Rolls having a steel surface are also known from prior art—one example being disclosed in U.S. Pat. No. 6,203,307. In the hot soft nip calender disclosed in the patent, rolls with a steel outer surface are used as calender rolls to be heated. In traditional soft calendering the heat amounts transferred are, however, considerably smaller than in long nip calendering.

10 [0008] Arrangements in which the wear resistance of the steel roll has been provided by coating are known from prior art. Some such arrangements are disclosed in U.S. Pats. Nos. 4,452,647 and 5,167,068.

15 [0009] With respect to prior art, reference is also made to US-A-5,334,125 and EP-A-369 968. U.S. Pat. No. 5,334,125 discloses a martensite roll which has a cast-iron shell. The surface layer of the roll shell is hardened and tempered such that the structure of the surface layer of the roll shell is martensitic. Published EP application 369 968 discloses an arrangement in a paper machine, in which the surface properties of a roll and/or rolls are affected by regulating the temperature of the roll surface by means of an external heating device. In the arrangement, such a combination of a heating device and a roll coating is used that the heating radiation  
20 penetrates through the paper or only directly to the roll surface but does not heat the roll itself at a greater depth.

[0010] A very long nip, typically being over 30 mm, and high temperatures, the surface temperature of the roll typically being over 160°C (the interior of the roll can be even considerably hotter), and possibly moisturizing of the paper/board web with water or steam are needed in the long nip calendering process. These factors do not enable the manufacture of the machine, especially of the thermo roll of the nip, by means of the traditional technique, or, if manufactured traditionally, the machine has a low fault tolerance in case of a process failure.

## SUMMARY OF THE INVENTION

[0011] In modern paper and board machine rolls, particularly nip rolls, which withstand dramatic changes in the process conditions are needed, and it is an important object of the invention to provide such a roll.

5 [0012] A special object of the invention is to provide a long nip calender roll that withstands the high thermal stresses caused by the long nip process and enables an efficient heat transfer to paper.

[0013] It is an object of the invention to provide a roll resistant to thermal shock. Thermal shock has been dealt with, e.g. in the book "The Science and Engineering of  
10 Materials" by Donald R. Askeland, pp. 740–741, Chapman & Hall, 1996 (Third S.I. Edition).

[0014] An object of the invention is also to provide a roll that withstands rapid temperature changes.



## BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Not applicable.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The problem underlying the invention can be solved in a new and inventive way by changing the material used from cast iron to steel, meaning that, according to the invention, the heatable thermo roll of a long nip calender is manufactured of steel.

[0017] The roll according to the invention withstands thermal shock and its thermal shock coefficient is over  $6000 \text{ W/m}^2$ , which is due to the properties of the roll: ductility, very high strength properties, wear resistance. A roll having, at the same time, these three important qualities, with which considerable advantages are achieved, is not known from prior art. The material of the roll according to the invention is pure and homogeneous in the thickness direction of the wall; most appropriately the entire layer involved in the heat transfer process is homogeneous, i.e. comprises one phase, i.e. one crystal structure. Most advantageously the roll wall is martensite or bainite and does not contain retained austenite. The roll may also be entirely homogeneous.

[0018] The dynamic properties of the roll according to the invention are at a high level, whereby the vibration problems are diminished.

[0019] The properties of the roll according to the invention, most appropriately a steel roll in a quenched and tempered state, are preferably the following: surface hardness is  $400\text{--}500 \text{ HV}_{20}$ , modulus of elasticity over  $200,000 \text{ MPa}$ , tensile strength over  $1,000 \text{ MPa}$ , bending fatigue strength over  $350 \text{ MPa}$ , thermal conductivity over  $30 \text{ W/mK}$ , elongation at fracture over  $7 \%$ , and dynamic ductility over  $20 \text{ J}$ .

[0020] The roll according to the invention is also particularly well suitable for use in future processes, since it is very durable thanks to good ductility, strength and wear resistance properties and, in addition, its structure is very homogeneous, which also adds to its durability.

[0021] The material of the roll according to the invention is most preferably tempering steel and its crystal structure is most appropriately martensitic or bainitic. Most advantageously the material of the roll according to the invention is homogeneous tempering steel which has been induction hardened and tempered.

5 [0022] In this description a nip roll refers to a roll forming a nip with another roll, in which the contact between the rolls is usually given in MPa units and the nip length is over 4 mm.

[0023] According to an advantageous characteristic of the invention the surface properties, e.g. hardness, of the roll can be altered, if necessary, by hard coating the  
10 roll, whereby the hardness of the base material of the roll may be of the order of 250 MPa.

[0024] The roll according to the invention advantageously has one or more of the following properties:

- The shell of the roll is forged from a steel slab or it is a steel casting or  
15 otherwise manufactured of steel, such as, by bending from a plate.
- The roll is heated, for example by means of a heat transfer medium flowing inside the roll, e.g. by means of water, steam, oil, air; by resistors, external or internal induction; there can be a heat production unit inside the roll, or by means of a combination of two or more of the above. The roll is most  
20 appropriately heated so that the heat is distributed evenly over the surface of the shell of the roll.
- The steel shell of the roll may be coated (e.g. welding or plasma spraying) with a wear resistant material, with which the surface hardness is increased. The coating may also serve as a protection against chemical wear.
- 25 - The steel shell of the roll is surface hardened or through hardened or unhardened. Suitable hardening methods include, for example, induction hardening, flame hardening, laser hardening, case hardening, nitrate

hardening or other such heat treatment according to the quenching and tempering treatment.

- The steel roll can also be manufactured of one or more different materials.
- The roll surface made of a different material may also be a several  
5 millimeters thick shell enveloping the inner part of the roll, e.g. a tempering steel shell over a cast iron central portion.
- The structure of the roll may enable the evaporation of water in the nip. The roll may be a conventional roll or the roll may be formed only of a rotating shell, such as a roll similar to the one marketed by Metso Paper, Inc. under  
10 the trademark SymRoll.
- The roll can be cooled and heated by means of a medium, e.g. water. The properties of the roll surface, e.g. hardness and thermal conductivity, may vary in the cross machine direction (direction of the roll axis).

[0025] Thermal shock i.e. heat shock in materials is affected by several factors: the  
15 coefficient of thermal expansion, thermal conductivity, the modulus of elasticity, fracture stress and phase transformations. Thermal shock can thus be derived from

the equation  $\frac{\sigma_f k}{E \alpha}$ , where

$\sigma_f$  = the fracture stress of the material,

$k$  = the thermal conductivity,

20  $E$  = the modulus of elasticity, and

$\alpha$  = the linear coefficient of thermal expansion.

[0026] The roll according to the invention is advantageously suitable for use as a nip roll of a paper or board machine, especially in nips in which a great heat transfer from the roll to the web occurs. Advantageous applications are, for example, thermo  
25 roll of a calender (e.g. super-, multiroll, OptiLoad, long nip and soft calenders).

[0027] The roll according to the invention withstands rapid temperature changes,

whereby, for example, it does not take as much time to change or clean it and, in addition, the heating and cooling phases, in which a lot of capacity is lost, naturally become considerably quicker.

[0028] Table 1 shows in an exemplifying manner a comparison between the material properties of a prior art roll manufactured of chill casting material and of a roll manufactured of tempering steel according to a preferable application of the invention.

Table 1

Property	Chill casting	Tempering steel
<b>Tensile strength at fracture</b>	about 250 N/mm <sup>2</sup>	about 1400 N/mm <sup>2</sup>
<b>Yield stress</b>	no yield stress (white cast iron)	about 1100 N/mm <sup>2</sup>
<b>Elongation A5</b>	no remarkable elongation less than 0.2 %	more than 8 %
<b>Surface hardness</b>	about 550-590 HV20	420-480 HV20 (through the entire shell of the roll)
<b>Thermal conductivity</b>	24 W/mK (white cast iron) surface layer about 10 mm	30-40 W/mK
<b>Thermal conductivity</b>	48 W/mK (grey cast iron) interior	